Research on the Performance Evaluation Model of Higher Education Teachers Based on the Improved Grey Clustering Analysis Method

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Abstract—**Effective performance evaluation of university teachers is supposed to guide teaching behaviors and teaching modes as well as improve teaching quality of higher education. In response to the complexity of performance evaluation of university teachers, this thesis proposes a performance evaluation model based on the improved grey clustering analysis method. Firstly, an index model for evaluating performance of university teachers is established with confirmed layers and index sets. Secondly, performance evaluation grades are given out and whitenization weight functions of grey clustering under different performance grades are established. Based on the standardization of index model, and taking weight into consideration, this thesis provides an improved grey clustering analysis method for performance evaluation of university teachers. Last but not the least, the model is verified through case study to prove its efficacy and availability, which lays a sound support for improving higher education.**

Index Terms—Higher education; University teachers; Performance evaluation; Grey clustering analysis method; Promotion of education ability; Model and algorithm

I. INTRODUCTION

Teachers, as a crucial part in higher education, play an important role in advancing teaching modes and the capability of higher education [3-4]. Therefore, the significance of establishing a system and model for evaluating performance of university teachers cannot be overlooked. Experts and scholars have discussed and analyzed such issue from different perspectives and acquired fruitful results [5-8]. Schools of higher education serve as a cradle for talent training. They are essential in disseminating, imparting and innovating knowledge useful for social and scientific development. Universities, as a result, are faced with the demand of adapting to social and scientific development [1-2].

However, the performance evaluation of university teachers is complicated system engineering. Current study is still far from enough. For example, the existing evaluation system draws much attention on parts rather than a comprehensive analysis; the evaluation target is sometimes mistaken and becomes distant from the purpose of improving education ability; the evaluation process is unclear, failing to deal with fuzzy information or resulting in improper integration of qualitative and quantitative evaluation. Therefore, this paper draws merits from previous studies with the intention of improving education ability, and proposes an improved grey clustering analysis method [11-13] for evaluating performance of university

teachers, so as to provide guidance and support for improving teaching modes in higher education.

II. PERFORMANCE EVALUATION MODEL OF UNIVERSITY TEACHERS

Under the principle of being scientific, comprehensive, objective, practical and adaptive, this thesis studies carefully the teaching ability, research ability, social service, talent training and ethics and moral development, all of which are primary indexes. Secondary indexes are formed after each primary index is detailed. Table 1 shows the performance evaluation model of university teachers.

TABLE I. TYPE SIZES FOR CAMERA-READY PAPERS

Performance index system	Primary index	Secondary index
Performance evaluation model of university teachers S	Teaching ability S_1	Innovation s_{11}
		Efficiency s_{12}
		Methodology s_{13}
		Results s_{14}
		Method s_{15}
		Altitude s_{16}
	Research ability S_2	Number of research projects s_{21}
		Proportion of advanced projects s_{22}
		Number of articles published s_{23}
		Proportion of advanced articles s_{24}
		Integration of industry-academia-research s_{25}
		Transformation of research results s_{26}
	Social service S_3	Student satisfaction s_{31}
		School satisfaction s_{32}
		Social contribution s_{33}
		Campus contribution s_{34}
		Committee and Broad Memberships s_{35}
	Talent training S_4	Number of students being trained s_{41}
		Yield s_{42}
		Echelon building of talents s_{43}
		Social practice of student s_{44}
	Ethics and moral development S_5	Vocational morality s_{51}
		Academic morality s_{52}
		Professional skill s_{53}

According to the performance index system, the index sets can be constructed, in which S^I refers to:

$$S^I = \left\{ S_1^{II}, S_2^{II}, S_3^{II}, S_4^{II}, S_5^{II} \right\} \tag{1}$$

The secondary index set S^{II} refers to:

$$\begin{cases} S_1^{II} = \left\{ s_{11}, s_{12}, s_{13}, s_{14}, s_{15}, s_{16} \right\} \\ S_2^{II} = \left\{ s_{21}, s_{22}, s_{23}, s_{24}, s_{25}, s_{26} \right\} \\ S_3^{II} = \left\{ s_{31}, s_{32}, s_{33}, s_{34}, s_{35} \right\} \\ S_4^{II} = \left\{ s_{41}, s_{42}, s_{43}, s_{44} \right\} \\ S_5^{II} = \left\{ s_{51}, s_{52}, s_{53} \right\} \end{cases} \tag{2}$$

III. PERFORMANCE EVALUATION PERFORMANCE EVALUATION MODEL OF HIGHER EDUCATION TEACHERS BASED ON THE IMPROVED GREY CLUSTERING ANALYSIS METHOD MODEL OF UNIVERSITY TEACHERS

A. Improved whitenization weight function

The whitenization weight function is a key link of grey clustering analysis. To make sure that the whitenization weight shares the same membership degree with the performance evaluation grade, we have to satisfy the premises that the whitenization weight function is a constant function changing with independent variable and that the whitenization weight functions of every two grades that are no adjacent to each other do not have intersections. And each whitenization weight function has the quantity value of 1 and on each side of the quantity value the function is monotonous. The improved whitenization weight function is constructed in Fig.1.
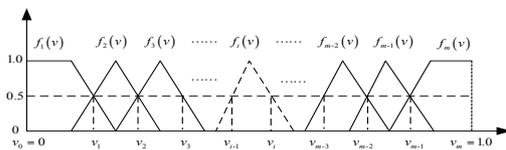
Figure 1.

According to Fig.1, the corresponding whitenization weight function model can be constructed as:

$$f_1(v) = \begin{cases} 0 & v \in \left[\frac{v_2 + v_1}{2}, 1 \right] \\ \frac{v_2 + v_1 - 2v}{2(v_2 - v_1)} & v \in \left[v_1, \frac{v_2 + v_1}{2} \right] \\ \frac{3v_1 - 2v}{2v_1} & v \in \left[\frac{v_1 + v_0}{2}, v_1 \right] \\ 1 & v \in \left[v_0, \frac{v_1 + v_0}{2} \right] \end{cases} \tag{3}$$

$$f_i(v) = \begin{cases} \frac{2v - v_{i-1} - v_{i-2}}{2(v_{i-1} - v_{i-2})} & v \in \left[\frac{v_{i-1} + v_{i-2}}{2}, v_{i-1} \right] \\ \frac{2v + v_i - 3v_{i-1}}{2(v_i - v_{i-1})} & v \in \left[v_{i-1}, \frac{v_i + v_{i-1}}{2} \right] \\ 0 & v \in \left[v_0, \frac{v_{i-2} + v_{i-1}}{2} \right] \cup \left[\frac{v_i + v_{i+1}}{2}, 1 \right] \\ \frac{3v_i - v_{i-1} - 2v}{2(v_i - v_{i-1})} & v \in \left[\frac{v_i + v_{i-1}}{2}, v_i \right] \\ \frac{v_i + v_{i+1} - 2v}{2(v_{i+1} - v_i)} & v \in \left[v_i, \frac{v_i + v_{i+1}}{2} \right] \end{cases} \tag{4}$$

where there is $2 \leq i \leq (m-1)$.

$$f_m(v) = \begin{cases} 1 & v \in \left[\frac{v_{m-1} + 1}{2}, 1 \right] \\ \frac{2v + 1 - 3v_{m-1}}{2(v_m - v_{m-1})} & v \in \left[v_{m-1}, \frac{v_{m-1} + v_m}{2} \right] \\ \frac{2v - v_{m-1} - v_{m-2}}{2(v_{m-1} - v_{m-2})} & v \in \left[\frac{v_{m-1} + v_{m-2}}{2}, v_{m-1} \right] \\ 0 & v \in \left[v_0, \frac{v_{m-1} + v_{m-2}}{2} \right] \end{cases} \tag{5}$$

B. Establishing performance evaluation grade

To effectively evaluate the grade of the subject, this thesis adopts a five-grade evaluation mechanism after consulting experts, scholars and leaders in the education sector while abiding by relevant systems and standards.

The five grades are excellent g_{exc}, good g_{goo}, mediocre g_{med}, general g_{gen} and poor g_{poo}.

In order to achieve the same membership scale of evaluation subjects, this thesis adopts a 0-1 grade to divide the performance evaluation interval. The excellent grade is 0.9-1.0, followed by the good grade, which takes up 0.8-0.9. Next is the mediocre grade, taking up 0.7-0.8, followed by the general grade, which takes up 0.6-0.7. And the last is the poor, taking up 0 -0.6. So, the grade set G of performance evaluation of university teachers is expressed as:

$$G = \left\{ g_{exc} \,|\, (0.9\text{-}1.0), \ g_{goo} \,|\, (0.8\text{-}0.9), g_{med} \,|\, (0.7\text{-}0.8), g_{gen} \,|\, (0.6\text{-}0.7), g_{poo} \,|\, (0\text{-}0.6) \right\} \tag{6}$$

C. Standardization of evaluation index

From the evaluation system, it can be seen that performance evaluation grades for different teachers are presented in different forms. Some are qualitative description and others are quantitative description. There are positive indexes, negative indexes and moderate indexes. Thus, we need to standardize these indexes to evaluate based on unified grade.

Qualitative indexes usually have fuzzy qualitative description. The fuzzy language needs to go through quantitative transformation according to grade of qualitative description. The finer the grade, the more definite the quantitative value is after transformation. This thesis adopts 0-1 scale to conduct quantitative transformation on qualitative indexes. 1 refers to excellent qualitative description and 0 refers to poor qualitative description. Other quantitative values are confirmed based on fuzzy description.

For positive quantitative index j, if the initial value is v_j, the maximum threshold of its corresponding index is v_j^{max} while the minimum is v_j^{min}, so the quantitative value u_j after standardization is:

$$u_j = \frac{v_j - v_j^{min}}{v_j^{max} - v_j^{min}} \tag{7}$$

For negative quantitative index j, if the initial value is v_j, the maximum threshold of its corresponding index is $v_j^{\max}$ while the minimum is $v_j^{\min}$, so the quantitative value u_j after standardization is:

$$u_j = \frac{v_j^{\max} - v_j}{v_j^{\max} - v_j^{\min}} \tag{8}$$

For moderate quantitative index j, if the initial value is v_j, the maximum threshold of its corresponding index is $v_j^{\max}$ while the minimum is $v_j^{\min}$, so the quantitative value u_j after standardization is:

$$u_j = 1 - \frac{\left| v_j - \left(v_j^{\max} + v_j^{\min} \right)/2 \right|}{\left| \left(v_j^{\max} - v_j^{\min} \right)/2 \right|} \tag{9}$$

D. Establishing the performance evaluation model

Based on the grades of performance evaluation of university teachers, we can work out the whitenization weight function of five grades, namely $f_{g_{poo}}(v)$, $f_{g_{gen}}(v)$ $f_{g_{med}}(v)$ $f_{g_{goo}}(v)$ and $f_{g_{exc}}(v)$. There is $v_0 = 0$, $v_1 = 0.6$ $v_2 = 0.7$ $v_3 = 0.8$ $v_4 = 0.9$ and $v_5 = 1.0$.

The whitenization weight function $f_{g_{poo}}(v)$ corresponding to the poor grade g_{poo} is:

$$f_{g_{poo}}(v) = \begin{cases} 0 & v \in [0.65,1] \\ \dfrac{1.3 - 2v}{0.2} & v \in [0.6, 0.65] \\ \dfrac{1.8 - 2v}{1.2} & v \in [0.3, 0.6] \\ 1 & v \in [0, 0.3] \end{cases} \tag{10}$$

The whitenization weight function $f_{g_{gen}}(v)$ corresponding to the general grade g_{gen} is:

$$f_{g_{gen}}(v) = \begin{cases} \dfrac{2v - 0.6}{1.2} & v \in [0.3, 0.6] \\ \dfrac{2v - 1.1}{0.2} & v \in [0.6, 0.65] \\ 0 & v \in [0, 0.3] \cup [0.75, 1] \\ \dfrac{1.5 - 2v}{0.2} & v \in [0.65, 0.75] \end{cases} \tag{11}$$

The whitenization weight function $f_{g_{med}}(v)$ corresponding to the moderate grade g_{med} is:

$$f_{g_{med}}(v) = \begin{cases} \dfrac{2v - 1.3}{1.2} & v \in [0.65, 0.75] \\ 0 & v \in [0, 0.65] \cup [0.85, 1] \\ \dfrac{1.7 - 2v}{0.2} & v \in [0.75, 0.85] \end{cases} \tag{12}$$

The whitenization weight function $f_{g_{goo}}(v)$ corresponding to the good grade g_{goo} is:

$$f_{g_{goo}}(v) = \begin{cases} \dfrac{2v - 1.5}{1.2} & v \in [0.75, 0.85] \\ 0 & v \in [0, 0.75] \cup [0.95, 1] \\ \dfrac{1.9 - 2v}{0.2} & v \in [0.85, 0.95] \end{cases} \tag{13}$$

The whitenization weight function $f_{g_{exc}}(v)$ corresponding to the excellent grade g_{exc} is:

$$f_{g_{exc}}(v) = \begin{cases} 1 & v \in [0.95, 1] \\ \dfrac{2v - 1.7}{0.2} & v \in [0.85, 0.95] \\ 0 & v \in [0, 0.85] \end{cases} \tag{14}$$

In the model, with the weight of index k in the secondary set S^{II} to be obtained, the grey clustering coefficient of whitening weight function $f_{g_l}(v)$ corresponding to index k under different performance evaluation grades is calculated as $\delta_{kl}^{II} = f_{g_l}(v_k)$. Based on the weight w_k^{II} of index k in the secondary index set S^{II}, the comprehensive clustering coefficient δ_l^{I} is calculated as:

$$\delta_l^{I} = \sum_{k=1}^{n_k} \left(w_k^{II} * \delta_{kl}^{II} \right) = \sum_{k=1}^{n_k} \left(w_k^{II} * f_{g_l}(v_k) \right) \tag{15}$$

If the weight of index q in the primary set is w_q^{I}, the comprehensive clustering coefficient δ_l^{I} of all index q under different performance evaluation grades is:

$$\delta_l = \sum_{q=1}^{n_q} \left(w_q^{I} * \delta_l^{I} \right) = \sum_{q=1}^{n_q} \left(w_q^{I} * \sum_{k=1}^{n_k} \left(w_k^{II} * \delta_{kl}^{II} \right) \right) \tag{16}$$

The bigger the comprehensive grey clustering coefficient δ_l is, the closer the grade of the evaluated teacher to grade l and vice versa. So, comprehensive grey clustering coefficient δ_l enables us to figure out in which grade the subject falls.

E. Realization of performance evaluation algorithm

As is discussed above, the performance evaluation model of higher education teachers based on the improved grey clustering analysis method is exercised as below:

Step1 Construct the performance evaluation model of university teachers and obtain the primary index set and the secondary index set according to Equ. (1) and (2).

Step2 Obtain the improved grey weight function model according to Equ. (3)- (5).

Step 3 Construct the grade of performance evaluation of university teachers according to Equ. (6).

Step 4 Standardize qualitative indexes and quantitative indexes according to Equ. (7)-(9) and description in Section 3.3 to unify the standard.

Step 5 Construct the whitening weight function model of performance evaluation according to Equ. (10)- (15).

Step 6 Obtain the comprehensive grey clustering coefficient of subjects under different performance evaluation grades according to Equ. (16)- (17).

Step 7 Obtain the grade of the subject based on the comprehensive grey clustering coefficient.

IV. CASE STUDY AND ANALYSIS

This thesis explains the model and the algorithm with the study of the performance evaluation of teachers in a university. The performance of a teacher is confirmed through the combination of several ways including expert scoring, questionnaire and statistics. These data are standardized as required, and the result of which is shown in Table II.

Therefore, the sequence of comprehensive grey clustering coefficient of this teacher is $\delta = (0.375, 0.344, 0.175, 0.051, 0.052)$, from which we can see the teacher is in the excellent grade.

Thus, construct the whitening weight function model of performance evaluation of teachers and obtain the grey clustering coefficient, as shown in Table III and IV.

TABLE II.
PERFORMANCE EVALUATION OF TEACHERS

Primary index	Weight	Secondary index	Weight	Preliminary data	Standardized data	Type of index
S_1	0.30	s_{11}	0.15	0.90	0.90	qualitative
		s_{12}	0.25	0.85	0.85	qualitative
		s_{13}	0.15	0.90	0.90	qualitative
		s_{14}	0.20	0.80	0.80	qualitative
		s_{15}	0.10	0.95	0.95	qualitative
		s_{16}	0.15	0.95	0.95	qualitative
S_2	0.20	s_{21}	0.10	2.5	0.80	quantitative
		s_{22}	0.20	0.80	0.80	quantitative
		s_{23}	0.10	8	0.80	quantitative
		s_{24}	0.20	0.75	0.75	quantitative
		s_{25}	0.20	0.65	0.65	qualitative
		s_{26}	0.20	0.35	0.35	quantitative
S_3	0.15	s_{31}	0.20	0.95	0.95	qualitative
		s_{32}	0.20	0.90	0.90	quantitative
		s_{33}	0.25	0.80	0.80	qualitative
		s_{34}	0.20	0.85	0.85	qualitative
		s_{35}	0.15	0.50	0.50	qualitative
S_4	0.20	s_{41}	0.15	125	0.83	quantitative
		s_{42}	0.30	0.98	0.98	quantitative
		s_{43}	0.35	0.85	0.85	qualitative
		s_{44}	0.20	0.75	0.75	qualitative
S_5	0.15	s_{51}	0.30	0.95	0.95	qualitative
		s_{52}	0.30	0.95	0.95	qualitative
		s_{53}	0.40	0.95	0.95	qualitative

TABLE III.   GREY CLUSTERING COEFFICIENT OF SECONDARY INDEX

Secondary index	Evaluation grade				
	g_{exc}	g_{goo}	g_{med}	g_{gen}	g_{poo}
s_{11}	0.500	0.500	0	0	0
s_{12}	0	1.000	0	0	0
s_{13}	0.500	0.500	0	0	0
s_{14}	0	0.500	0.500	0	0
s_{15}	1.000	0	0	0	0
s_{16}	1.000	0	0	0	0
s_{21}	0	0.500	0.500	0	0
s_{22}	0	0.500	0.500	0	0
s_{23}	0	0.500	0.500	0	0
s_{24}	0	0	1.000	0	0
s_{25}	0	0	0	1.000	0
s_{26}	0	0	0	0.083	0.917
s_{31}	1.000	0	0	0	0
s_{32}	0.500	0.500	0	0	0
s_{33}	0	0.500	0.500	0	0
s_{34}	0	1.000	0	0	0
s_{35}	0	0	0	0.333	0.667
s_{41}	0	0.800	0.200	0	0
s_{42}	1.000	0	0	0	0
s_{43}	0	1.000	0	0	0
s_{44}	0	0	1.000	0	0
s_{51}	1.000	0	0	0	0
s_{52}	1.000	0	0	0	0
s_{53}	1.000	0	0	0	0

TABLE IV.   GREY CLUSTERING COEFFICIENT OF PRIMARY INDEX

Primary index	Evaluation grade				
	g_{exc}	g_{goo}	g_{med}	g_{gen}	g_{poo}
S_1	0.120	0.150	0.030	0	0
S_2	0	0.040	0.080	0.043	0.037
S_3	0.045	0.064	0.019	0.008	0.015
S_4	0.060	0.094	0.046	0	0
S_5	0.150	0	0	0	0

V. CASE STUDY AND ANALYSIS

To better guide teaching behaviors and teaching modes, and improve the quality of higher education, this thesis proposes a performance evaluation model of university teachers based on the improved grey clustering analysis method. By establishing the index model and improved whitenization weight function, this thesis also standardizes indexes and acquires grades of performance evaluation of teachers. The model is easy to calculate and has a clear physical significance. It provides guidance for improving teaching ability of university teachers.

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